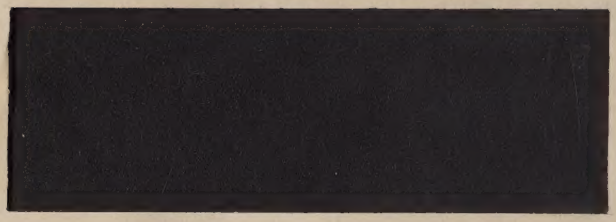
Instruction Manual

MP MASTER
MA32732

AIRCO® Temescal
2850 Seventh Street, Berkeley, California 94710



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A DIVISION OF AIRCO, INC.

SALES OFFICES:

California, Mountain View 94040
1901 Old Middlefield Way
415/965-0400

California, South Pasadena 91030
1510 Oxley Street, Suite A
213/682-2121

Connecticut, Wilton 06897
Merwin Building
203/762-8361

Illinois, Broadview 60153
2001 West 16th Street
312/681-8950 ext. 259

Massachusetts, Needham 02192
33 Marsh Rd
617/449-4080

New Jersey, Murray Hill 07974
100 Mountain Avenue
201/464-2400 ext. 248

Ohio, Cleveland 44129
5700 Pearl Road
216/842-9330

Washington, D.C. 20005
1030-15th Street N.W.
202/296-4775

Australia and New Zealand
Austral Engineering Supplies Pty. Ltd.
Mary Street
Ermington, N.S.W. 2115 Australia
Telephone: 85-0211
TWX: 790-20179

Europe:
Airco Temescal N.V.
Building 70, P.O. Box 7709
Schiphol-Oost, Netherlands
Telephone: 020-454577
TWX: 844-16645

Airco Temescal N.V.
1 Lawnswood Close
Cowplain nr. Portsmouth
Hants., England
Telephone: Waterlooville 4214

Japan
Hakuto Company Ltd.
Foreign Division
P.O. Box 25
Tokyo Central, Japan
Telephone: 03-503-3711

Hakuto Osaka
Umeda-CHO 17-1
Kita-Ku, Osaka
Telephone 06-345-1517

AIRCO Temescal 2850 Seventh Street, Berkeley, California 94710, Tel: (415) 841-5720, TWX: 910 366-7366 Western Union Telegram FAX (BBX)

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A.E. m.

INFICON XMS-1

XMS-3

THIN FILM DEPOSITION CONTROLLER

PRELIMINARY

INSTRUCTION MANUAL

XMS-3

THIN FILM DEPOSITION CONTROLLER

INFICON, INC., 5 Adler Drive, East Syracuse, New York 13057
TEL 437-0377

SALES REP IN MELBOURNE
@ PETE FLETCHER #724-4701

WARNING

The XMS uses M.O.S. devices in its memory circuits which may be damaged if exposed to large static discharges. If at any time it is necessary to remove the XMS-310 printed circuit board, first touch chassis. Removal and handling should be executed touching only the outside edge of the board.

WARRANTY

ONE YEAR WARRANTY ON LABOR AND PARTS IF FAILURE IS DUE TO DEFECTS IN MATERIALS OR WORKMANSHIP. QUARTZ CRYSTALS ARE EXCLUDED. NINETY DAY WARRANTY ON SENSOR HEAD.

WARRENTY TERMS: Please contact factory for authorization to return material for warranty claim. All material returned must be shipped freight prepaid.

Note: These instructions do not provide for every contingency that may arise in connection with the installation, operation or maintenance of this equipment. Should further assistance be required, please contact Inficon, Inc.

PRELIMINARY
INSTRUCTION MANUAL

XMS-3
THIN FILM DEPOSITION CONTROLLER

January 1974

INFICON, INC., 5 Adler Drive, East Syracuse, New York 13057

TABLE OF CONTENTS

		Page
1.0	General Information	1-1
1.1	Receiving, Handling and Storage	1-1
1.2	Specifications	1-1
1.2.1	Physical Data	1-2
1.2.2	Accessories and Parts	1-3
2.0	General Description	2-1
2.1	Front Panel	2-1
2.2	Rear Panel Connections	2-6
2.3	Thickness Sensor	2-9
3.0	Preliminary Checkout	3-1
3.1	Initial Setup and Programming	3-1
3.2	Test Procedure	3-5
3.3	Manual Power Controls	3-6
4.0	Installation	4-1
4.1	Installation in Coating System	4-1
4.2	Rear Panel Connections	4-1
4.2.1	Interface (J6)	4-1
4.2.2	Source Power (J8)	4-5
4.2.3	Sensor 1, 2, 3	4-5
4.3	Installation of Sensor Head	4-5
4.3.1	Replacing the Crystal	4-7
4.4	Final Programming	4-7
5.0	Calibration	5-1
5.1	Theory of Operation	5-1
5.2	Calibration Procedure	5-3
5.2.1	Density	5-3
5.2.2	Z-ratio	5-4
5.2.3	Tooling	5-5

LIST OF ILLUSTRATIONS

Figure		Page
2-1	XMS-3 Front Panel	2-2
2-2	XMS-3 Rear Panel	2-7
2-3	Exploded View of Sensor	2-10
3-1	Sample Deposition Run	3-4
4-1	Typical Installation	4-2
4-2	J6 System Interface	4-3
4-3	Interface Circuits	4-4
4-4	J8 Source Power	4-6

1.0 GENERAL INFORMATION

The Inficon Model XMS Thin Film Deposition Controller series consists of the following items:

a. Thin Film Deposition Controller
b. Standard water-cooled sensor head (Part No. 321-20)
c. Mating connectors
d. Hand-held power control
e. Five (5) spare crystals
f. Instruction manual
g. Power cord
h. Oscillator cable.

This publication covers the installation and operation of the instrument.

1.1 Receiving, Handling and Storage

Upon receipt of the Thin Film Deposition Controller, examine it immediately for any damage that may have occurred in transit. Immediate examination is especially important if rough handling is evident. If damage is found, a claim should be filed with the transportation company immediately, and Inficon should be promptly notified.

Spare crystals should be stored in their shipping containers.

1.2 Specifications

Thickness Measurement Range (three automatic ranges)	0 to 999.9 kÅ
Thickness Limits (two set points)	0 to 999.9 kÅ
Rate Control Range	0 to 999Å/second
Thickness Display Resolution	1Å from 1 to 9.999 Å 10Å from 10 to 99.99 kÅ 100Å from 100 to 999.9 kÅ
Rate Display and Control Resolution	1Å /second
Rise Time	0.1 to 99.9 minutes

Soak Time (two set points)	0.1 to 99.9 minutes
Maximum Power	0 to 99%
Idle Power	0 to 99%
Gain	0 to 99
Density	0.80 to 99.99 gm/cc
Z-ratio	0.100 to 1.999
Control Voltage Out (three source outputs)	0 to -10 Vdc @ 20 mA
Power (both units)	± 15%, 115/220 volts, 50-60 Hz, 57 watts
Operating Temperature	
Instrument	0 to 50°C
Sensor Head	-20 to 105°C
External Control Inputs	All require 60 to 220 Vac
Start	
Zero	
Stop	
Inhibit 1 (Crystal Failure Abort Enable)	
Inhibit 2 (holds unit in soak)	
Maximum Power Abort Enable	
Control Outputs	Solid state relays; maximum
Rise, Soak or Deposit (internally selectable)	220 Vac, rated at 3 amps
Thickness 1	
Thickness 2	
Abort	
Shutter 1	
Shutter 2 (XMS-3 only)	
Shutter 3 (XMS-3 only)	

1.2.1 Physical Data

XMS-1 and XMS-3	Weight: 25 lbs; 5-1/4" H x 16-3/4" W x 17-1/2" D; rack mountable.

TR-1	Weight: 6 lbs; 5-1/4" H x 19" W x 17-1/2" D
Oscillator	Weight: 9 oz; 7/8" H x 1/8" W x 2-1/4" L; includes 3" coax terminated in BNC for connection to vacuum feed-through and 10" multiconductor cable for connection to XMS.
Sensor	Weight: 4 oz; 1-3/8" diameter x 5/16" thick; supplied with 30" of 1/8" OD copper water-cooling lines and 30" coax terminated in Microdot 132-0112 connector.

1.2.2 Accessories and Parts

	Part No.
Sensor Head for thermal deposition systems. Complete with oscillator (321-40), interconnecting cables, water lines and five (5) spare crystals (321-25).	321-20
Sputtering Thickness Sensor for sputtering and thermal deposition systems. Complete with oscillator (321-40) interconnecting cables, integral water lines and five (5) spare crystals (321-25).	321-50
Bakeable Sensor Head for temperatures up to 450°C. Includes integral 2-3/4" diameter flange (copper gasket) with 30" water lines.	321-72
Sensor Crystals (package of 5)	321-25
Sputtering Sensor Crystals (package of 5)	321-55
Instrumentation Feedthrough for baseplate mounting in 1" bolt hole, single coaxial, double water line.	321-201
Instrumentation Feedthrough, single coaxial, double water line, 2-3/4" diameter flange (copper gasket).	321-202
Recorder Output for Thickness and Rate (0 to 10 Vdc)	XMS-340

TR-1 Tape Reader used only with XMS-3. The TR-1 is capable of entering into XMS-3 a total program or changing particular process parameters during a deposition.

2.0 GENERAL DESCRIPTION

2.1 Front Panel (Figure 2-1)

The following is a description of operational characteristics of all switches and indicators located on the front panel:

a. Zero

Depressing resets accumulated thickness and establishes a new reference for the unit. Elapsed time of soak or deposition is also zeroed with this key. If the source output exceeds the maximum power set point, this indicator will light and flash.

b. Start

Depressing initiates a programmed run. If the unit is in the stop mode (stop lamp on), pressing this switch once resets the stop mode, lights the start button and selects layer 1. This readies unit to start with a second push of the start button.

c. Stop

Pressing this switch shuts down the entire unit. That is, all source power outputs return to zero and the XMS can not be restarted until start reset has been initiated. Any time the unit is in the stop mode, the switch will be lit.

d. T/X

Pressing this switch (orange pushbutton) allows operator to view in the displays elapsed time from start of deposition (Group 1), percent of crystal life used (Group 2) and total accumulated frequency shift referenced to new crystal (Group 3). Percent is based on 1.5 MHz = 100%. Failure of the sensor crystal is indicated by the flashing of this lamp.

e. Layer

The XMS-3 will control three sources from three sensors in any combination. The small switches labeled 1, 2 and 3 indicate, when lit, which layer is being programmed or operated. Pressing any one of these switches allows the operator to manually select desired layer. Active layer can not be changed after a layer is started. Any layer can be programmed at any time

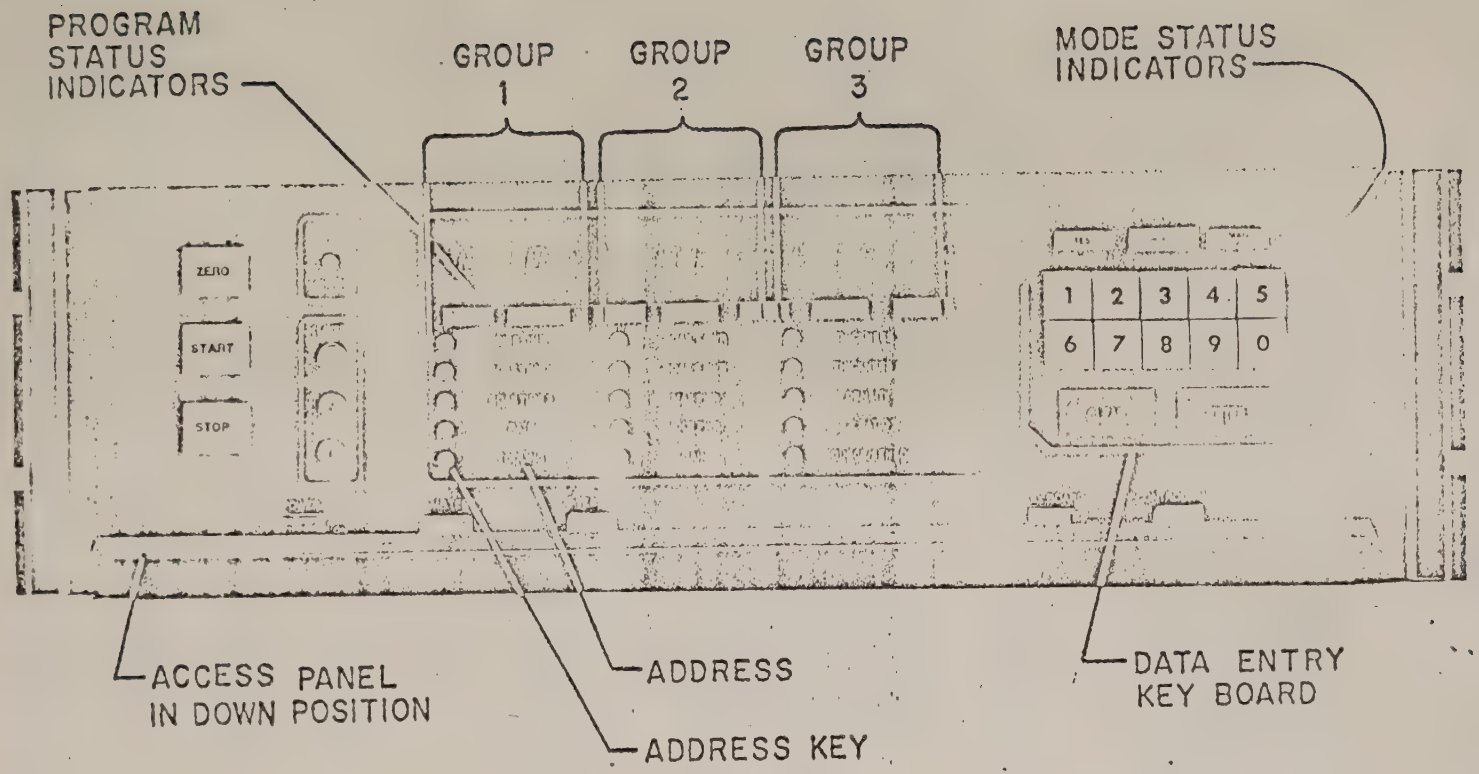


Figure 2-1 XMS Front Panel

by first going to the program mode, then selecting layer. Leaving the program mode automatically returns layer selection to the active layer.

f. Display and Programmable Functions

The numerical displays, data address and address keys are presented in three groups. When program data are being displayed, one address and the corresponding display will be illuminated. The keys located adjacent to the individual addresses provide (a) access to programmed data during a normal run and (b) address selection when in program mode.

Group I

Rise Time (0 to 99.9 minutes) - Time required to ramp power to soak power 1.

Soak Time 1 (0 to 99.9 minutes) - Time system remains at soak power 1.

Soak Time 2 (0 to 99.9 minutes) - For any selected time system will divide it between rising to soak power 2 (50%) and time at soak power 2 (50%).

Rate (0 to 999Å/second) - Desired deposition rate when system is in automatic control.

Tooling (20.0 to 499) - A programmable constant which allows instrument calibration for systems where there exists a geometric difference in the crystal sensor and substrate location.

Group II

Soak Power 1 (0 to 99%) - Power level for preconditioning new melt.

Soak Power 2 (0 to 99%) - Power level selected to produce a deposition rate close to desired auto-control rate.

Maximum Power (0 to 99%) - Level which limits the maximum any output power can exceed.

Idle Power (0 to 99%) - When thickness 2 is reached, deposition power returns to this preselected level.

Gain (0 to 99) - Loop constant which is experimentally determined to achieve most stable automatic rate control.

Group III

Thickness 1 (0 to 999.9 kÅ) - Provides a one second duration solid state relay closure when thickness exceeds preset value.

Thickness 2 (0 to 999.9 kÅ) - Terminates deposition cycle when thickness displayed equals preset value. Solid state relay closure for one second is also provided. Thickness 1 must be equaled or exceeded before thickness 2 becomes operative.

Density* (0.800 to 99.99 gm/cc) - Value determined by type of material being evaporated.

Z-ratio* (0.100 to 1.990) - Value determined by elastic properties of material being evaporated. Section 5.0 describes the concept of Z-match and lists values for some common materials.

Source/Sensor* (1-3/1-3 XMS-3 only) - Unit will accommodate three sources and three sensors with the ability to accept any source/sensor combination at all three layers of deposition.

g. Status Indicators

A group of indicators located directly below displays which give visual indication of state of the automatic run:

Rise
Soak 1
Soak 2
Deposition
Thickness 1
Thickness 2
Idle

* These quantities can not be entered or changed when the program is in any power control mode.

h. Data Entry Keyboard

The keyboard is activated by placing the unit into the program mode (blue pushbutton behind door) (program status lamp illuminated). Clear key clears displayed data only and does not effect data in memory. New data are entered via the enter key.

The following controls are located behind the hinged door at the bottom of the front panel:

a. Power On/Off Switch

When in the on position, this switch supplies ac line power to the unit and activates the auxiliary battery circuit. The battery is continually charging when the unit is on and line power is present. Ac power interruption places the unit on battery operation and will maintain program memory for 16 hours.

Caution: If the unit is turned off for extended period of time, be sure the power switch is in the off position or total discharge of the battery will occur.

b. Lamp Test

A momentary switch which allows testing of all lamps which do not operate with a front panel switch. Displays will show all 8's, zero flashing, T/X flashing, status lamps.

c. Test

Depressing test switch lights test indicator. A description of operation is contained in the preliminary checkout section.

d. Keyboard

Momentary switch which unlocks data entry keyboard; program indicator lamp is lit. Depressing switch a second time returns unit to normal. When system is placed in program, data address rise time is lit, and only the displays above this address are on.

e. Control Power (Auto/Manual)

When switch is in the manual position, manual power indicator is on and the output power level remains at last

value prior to switch change. Power level in manual mode may be controlled with hand-held controller. In automatic position deposition power controlled to establish desired rate.

2.2 Rear Panel Connections (Figure 2-2)

a. System Interface J6

All inputs are optically isolated from internal circuitry and require 60 - 220 volt ac signal between the common input (17, 18) and the functional input. Numbers in ( ) are pin connections.

Stop (14) - Momentary input terminates power to all sources and front panel stop lamp is illuminated.

Zero (5) - Momentary input zeros thickness reading and elapse time upon removal of signal.

Start (10) - Momentary input initiates start of programmed cycle. Constant input will automatically cycle XMS-3 through three layer deposition.

Note: Stop, zero or start inputs can be simultaneously activated. The occurrence of any two is treated as a stop. Momentary inputs to these controls should be a minimum of 1.0 second duration.

Inhibit 1 (9) (Crystal Abort Enable) - With this input activated, crystal failure will initiate an abort (stop) condition returning all source power control to zero. In a normal state crystal failure holds source power at the value existing just prior to failure.

Inhibit 2 (13) - A constant input will prevent program from proceeding beyond soak 1 power.

Maximum Power Enable (6) - When the input is activated, the XMS will stop when deposition power exceeds programmed maximum power level for a period in excess of 6 seconds. Deposition power is limited to maximum power setting when input to this function is inactive.

Common (17,18) - Circuit common to above inputs.

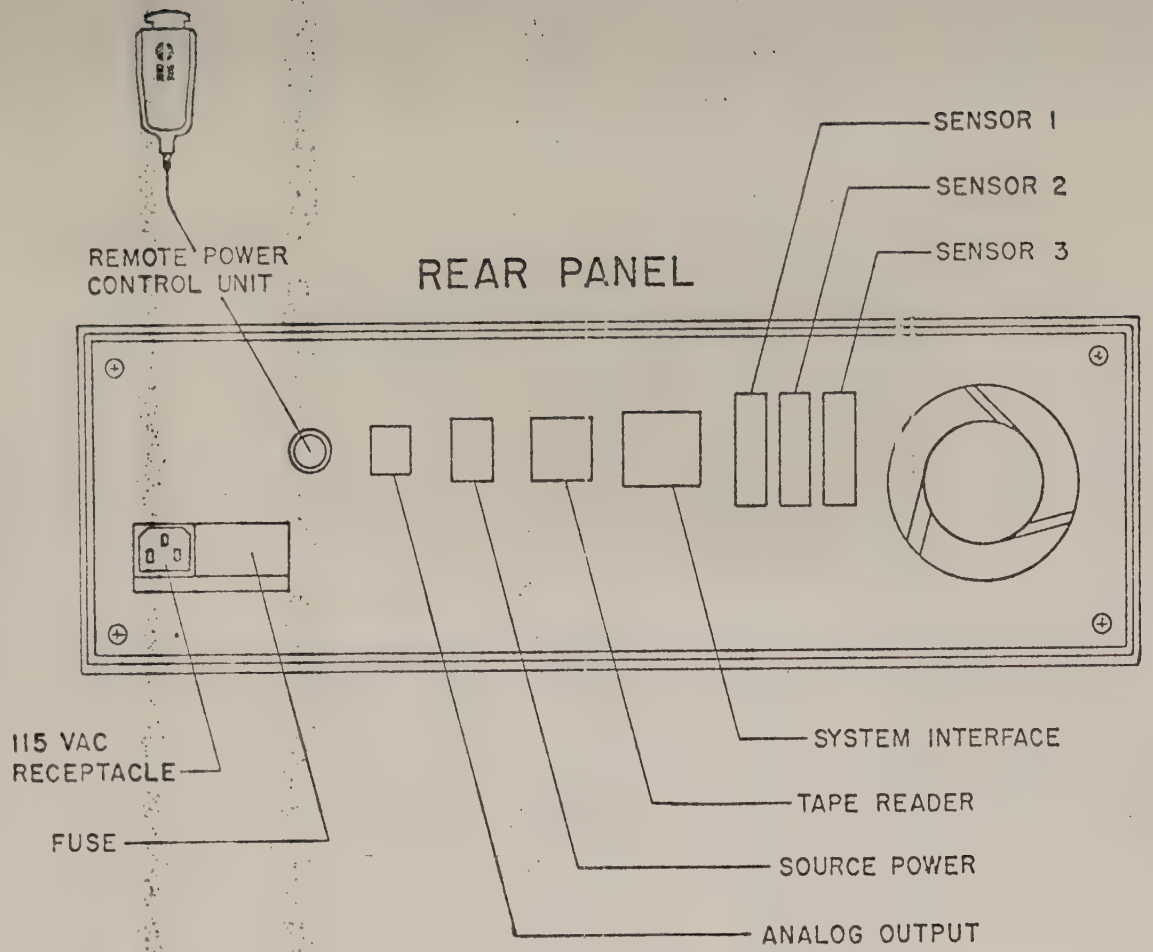


Figure 2-2 XMS Rear Panel

All outputs are rated at 220 volt ac, 3 amp rms. Numbers in ( ) are pin connections.

Cycle Triac (3,4) - This output may be internally wired to provide a circuit closure during any of the following programmed functions. The diodes to be connected are located on board XMS-350.

Rise	CR-39
Soak 1	CR-41
Soak 2	CR-38
Deposit	CR-40 (Factory Wired)

Abort (19,20) - Triac opens whenever maximum power is exceeded for greater than 5 seconds or system experiences crystal failure (see Maximum Power Enable and Inhibit 1 above).

Thickness 1 (1,2) - Circuit closure for 1.0 second when actual thickness reading exceeds preprogrammed thickness 1 while in automatic deposition.

Thickness 2 (23, 24) - Circuit closure for 1.0 second when actual thickness reading exceeds preprogrammed thickness 2, while in automatic deposition. Thickness 1 must be equaled or exceeded before thickness 2 becomes operative.

Layer 1 deposition (7,8), layer 2 deposition (11,12), layer 3 deposition (15,16) - Triac closes at beginning of deposition and opens at thickness 2 of the specified layer. These outputs are intended for shutter control in a multiple shutter system. For control of a single shutter the cycle triac can be used if uncommitted. If cycle triac is being used, layer 1, 2 and 3 should be paralleled for single shutter operation.

b. Source Power J8

The XMS-3 is capable of delivering three independent source control voltages with a range of 0 to -10 volts (0 - 100%) at a maximum current 20 mA. All three outputs are referenced to Pin 7 on the connector.

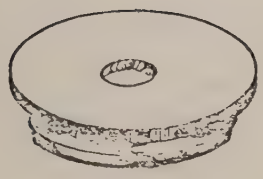
Control Source A	-	Pin 5
Control Source B	-	Pin 4
Control Source C	-	Pin 1
Reference	-	Pin 7

2.3 Thickness Sensor

Inficon's thin profile sensor head allows great flexibility in mounting in the vacuum chamber. In many cases the head can be mounted in the plane of the substrates for accurate and reproducible thickness measurement. The sensor head is designed for use in thermal evaporation.

An exploded view of the thickness sensor is shown in Figure 2-3. The 6 MHz AT-cut quartz crystal is mounted in the cover and held in place with the crystal pressure assembly. This design simplifies the replacement of the sensor crystal in the vacuum system.

The design of the sensor is such that the crystal is edge mounted. This maintains high crystal activity and freedom from mode hopping even with large mass loading. Thermal stability is provided using a small aperture and efficient water cooling. The exposed surface of the crystal is grounded to eliminate the effects of electrical disturbances such as RF field interference and accumulation of charged particles.



COVER
(HOUSES CRYSTAL)
PART NO. 321-20-1

CRYSTAL
PART NO. 321-25 (PKG. OF 5)

CERAMIC RETAINER
PART NO. 321-50-4

BODY ASSEMBLY
PART NO. 321-20-2

COAXIAL CABLE ASSEMBLY
PART NO. 321-50-5

WATER LINE : COPPER
PART NO. 321-20-6

WATER LINE : STAINLESS STEEL
PART NO. 321-20-6 SS

MOUNTING BRACKET
PART NO. 321-20-8

Figure 2-3 Exploded View of Sensor

3.0 PRELIMINARY CHECKOUT

This section is designed to help the new user of XMS to familarize himself with the basic operation of the instrument. In addition, it provides an excellent method for determining whether or not the unit is functioning properly.

3.1 Initial Setup and Programming

Proceed through the following steps, referring to Section 2.0 if there are questions regarding the function of various programmable data.

a. Connections

The unit requires 115 volt ac input power. In addition, connect the oscillator cable (321-40) supplied to input connector sensor 1 located at the rear of the instrument. The crystal sensor head (321-21) may now be connected to the oscillator cable by using the cable supplied with the head and a microdot to BNC adaptor. If a vacuum feed-through was purchased with the system, this can be used for the adaptor. The crystal sensor head is shipped with a crystal installed. For instructions on proper vacuum installation and changing of crystal, refer to Section 4.3.1.

b. Initial Turn-on

When the instrument is initially turned on, the following indicators will be lit:

Start	Group 1 Displays (000)
Layer 1	Rise Time Address
Program	

Test and Manual Power may be lit depending on switch settings.

In addition, the unit is preprogrammed in all three layers with the following data:

Rise	000
Soak Time 1	000
Soak Time 2	000
Rate	000
Tooling	100%
Soak Power 1	00
Soak Power 2	00

Maximum Power	90%
Gain	10
Thickness 1	0000
Thickness 2	0000
Density	1.00
Z-ratio	1.000
Source/Sensor	1/1

c. Programming

At this point the instrument is ready to accept the program data. The format and general rules for programming the XMS are listed below:

Data entry is a two-stage operation: i) enter data into displays and ii) enter data into memory.

Data existing in memory are not erased until new data are entered via the entry key.

Clear key clears displayed data only.

When entering new data, the first entry from the keyboard clears the displays and enters the depressed digit from the right. Therefore, new data may be entered into the displays directly without first clearing old data.

Successive digits are entered from the right as keyed.

Thickness 1 and thickness 2 incorporate autoranging. Full scale ranges are 9.999 kÅ, 99.99 kÅ and 999.9 kÅ. When entering data in these addresses, observe decimal shift if desired thickness is greater than 10 kÅ.

Data entered into the displays which are outside the boundary conditions specified for each function will not be accepted when the entry key is pressed (see Section 2.1(f)).

When data are entered via entry key, unit automatically steps to next address.

Zeros may be entered in thickness 1 if this control is not used in coating system.

Thickness 2 is the controlling function in terminating deposition; therefore, data entered are always greater than zero. For normal operation thickness 2 must be greater than or equal to thickness 1.

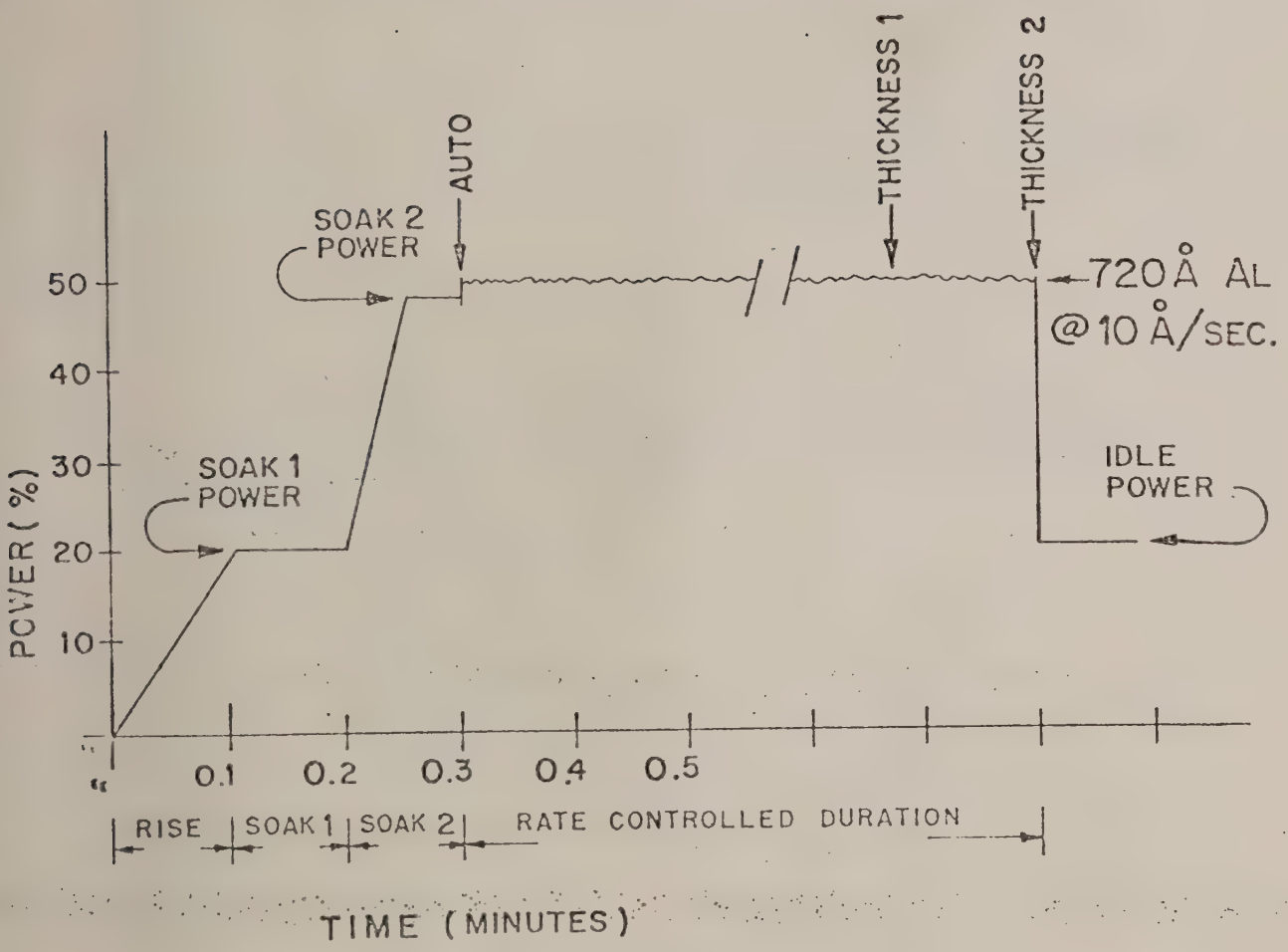
Individual address selection is achieved by pressing key adjacent to address.

The sample program below will help demonstrate the proper procedure. Figure 3-1 is a graphic representation of a typical run.

Rise Time	00.1 minute
Soak Time 1	00.1 minute
Soak Time 2	00.1 minute
Rate	10Å/second
Tooling	100%
Soak Power 1	20%
Soak Power 2	50%
Maximum Power	60%
Idle Power	20%
Gain	40
Thickness 1	0.700 kÅ
Thickness 2	0.720 kÅ
Density	1.00
Z-ratio	1.000
Source/Sensor	1-1

The first data to be entered are rise time. This is executed by pressing #1 key on the data keyboard and observing 0.1 on the display. Depressing the enter key places these data in memory and automatically steps the unit to the next address, soak time 1. The above sequence is continued entering the above format until source/sensor address is reached at which time entering 1-1 into the memory steps the instrument to ready to program layer 2 rise time. If it is desired to test or run multilayers, the procedure for programming layers 2 and 3 is exactly as above.

When using the XMS-3 in a multilayer coating system, the unit will automatically cycle through various layers. Starting with layer 1, a start command initiates the run; and when thickness 2 is achieved, the unit remains in layer 1 displaying final thickness and idle power. A second start command automatically shifts the unit to layer 2, and the program proceeds through this layer. If it is desired to use



OTHER DEPOSITION PARAMETERS:

TOOLING	100%
MAX. POWER	60%
GAIN	40
1ST THICKNESS	700 Å

Sample Deposition Run

Figure 3-1

the XMS-3 with a 1 or 2 layer system, enter zeros in the source/sensor of those layers to be omitted; For example, if the unit is to be used as a single layer system, zeros entered in source/sensor address layers 2 and 3 will insure that each start command will initiate a layer 1 deposition.

3.2 Test Procedure

After any or all data entries have been completed, the unit may be returned to the ready-to-start mode by depressing the momentary program switch. In this mode the following indicators should be lit:

Start
Layer 1
All numerical displays.

The internal test mode of operation in this instrument provides an excellent way to initially check out the unit prior to installing it into a system. Proceed with the steps listed below, noting the sequence of visual indicators:

a. Test switch on

Start lamp on
Layer 1 lamp on
Rate display 10Å/sec
Power display 00
Thickness display increasing in value

b. Press start

Start lamp off
Layer 1 lamp on
Rise time status lamp on
Power display increasing
Rate display 10Å/sec
Power equal to 20%; soak time 1 status lamp on
Rise time status lamp on for 50% of soak time 2
Soak time 2 status lamp on; soak power 2 rises to 50%
Thickness reading zeros; deposit status lamp on
Thickness reads 0.700 kÅ; thickness 1 status lamp on
Thickness equal to 0.720 kÅ; thickness 2 status lamp on; idle power status lamp on; power display reaches 20%
Thickness continues to increase
Start and layer 1 lamps on

c. Press T/X switch and elapse time should read 1.2 minutes.

d. Return test switch to off position.

The internal test mode is designed to simulate a constant rate of 10Å/sec. It is easy, therefore, to validate the performance of rate control, density and tooling factors. The preceding test run displayed a rate of 10Å/sec and a fixed power level when in deposition. This was due to the values of the function rate = 10Å/sec, density = 1.00 and tooling = 100%. Make the following program change and note the effect on displayed rate and deposition power when a test run is initiated.

a. Program
Rate = 20Å/sec
Tooling = 100%
Density = 1.000

Effect
Rate Display = 10Å/sec
Deposition power increasing, and zero key flashing when maximum power is reached

b. Program
Rate = 10Å/sec
Tooling = 400%
Density = 1.000

Effect
Rate Display = 40Å/sec
Deposition power decreasing

c. Program
Rate = 10Å/sec
Tooling = 100%
Density = 2.000

Effect
Rate Display = 5Å/sec
Deposition power increasing

In general while in test mode, any set rate greater than displayed rate should increase power and set rate less than displayed rate should decrease power.

3.3 Manual Power Controls

Because of the variations in types of coaters and control parameters, it is necessary to establish functions such as soak power 1 and soak power 2 by experimentation. The hand-held power controller

will allow an operator to determine these power levels. The controller connector is located at the rear of the instrument,and the following steps outline the proper use:

a. The instrument in ready-to-start mode (start lit)

b. Auto/Manual switch in manual position (manual indicator lit)

c. Desired layer indicator lit (proper source selection)

d. The controller contains a three-way switch. All positions are momentary and will return to rest when released. Pushing the switch forward or aft will cause the output control voltage to increase or decrease as observed on the displays. A downward pressure on the switch will immediately return all power to zero (stop).

4.0 INSTALLATION

4.1 Installation in Coating System (Figure 4-1)

A few precautions should be taken when interfacing the XMS and the coating system:

a. When rack or cabinet mounting the XMS, insure there is adequate ventilation.

b. The cooling fan located at the rear of the instrument should be free of obstructions.

c. Provide a ground strap between lug (rear panel) on unit to the common system ground point.

d. Ac line power should be removed from XMS whenever connections are being made.

e. At no time should the input or output power ratings be exceeded.

4.2 Rear Panel Connections (Figure 2-2)

4.2.1 Interface (J6)

All control inputs and outputs are accessible at this connector. Utilizing the mating connector and pins supplied, interconnections between the XMS and coating system may be no. 20 gauge wire or smaller. Precaution should be taken when soldering the pins to insure that solder does not flow to the contact portion of the pins. Figure 4-2 shows functions together with their pin location. For functional description of inputs and outputs, refer to Section 2.2.

The inputs are optical coupled to the internal circuits of the XMS. This type of coupling gives excellent isolation between the coating system and the XMS without placing special restrictions on the driving circuitry. A simple contact closure (Figure 4-3) supplying a 50-60 Hz signal of 60 to 220 volt rms will activate these inputs. Current requirements are less than 50 mA rms when using 220 volt input.

Caution: Due to the common input (5, 6), it is necessary to maintain ac line identity when interfacing the instrument to the coating system.

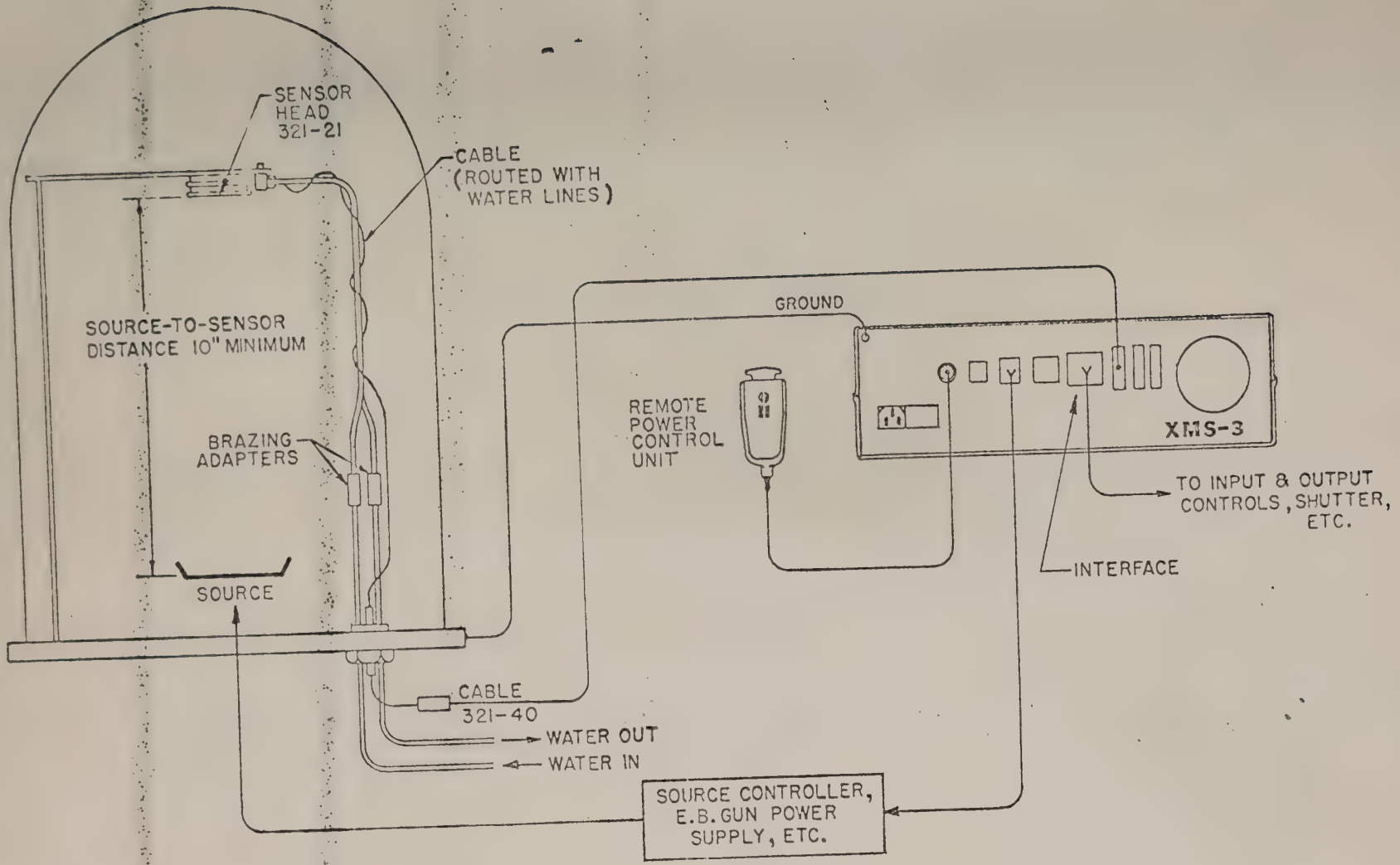


Figure 4-1 Typical Installation

Pin	Function
1, 2	Thickness 1 Triac
23, 24	Thickness 2 Triac
17, 18	Common Input
19, 20	Abort Triac
7, 8	Shutter 1 Triac
14	Stop Input
10	Start Input
11, 12	Shutter 2 Triac
15, 16	Shutter 3 Triac
5	Zero Input
13	Inhibit 2, Soak Hold
3, 4	Cycle Triac
21	---
22	---
9	Input, Crystal Fail Inhibit
6	Maximum Power Defeat (Abort) Input

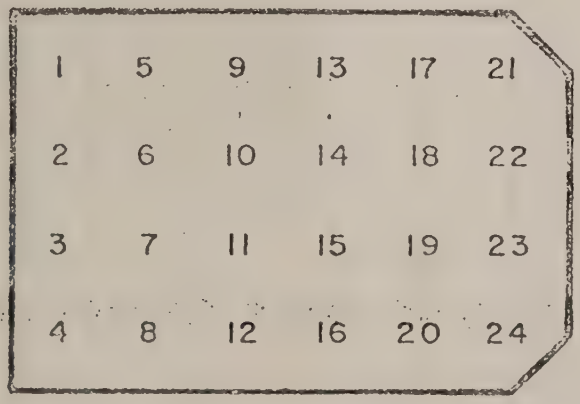


Figure 4-2 J6 System Interface

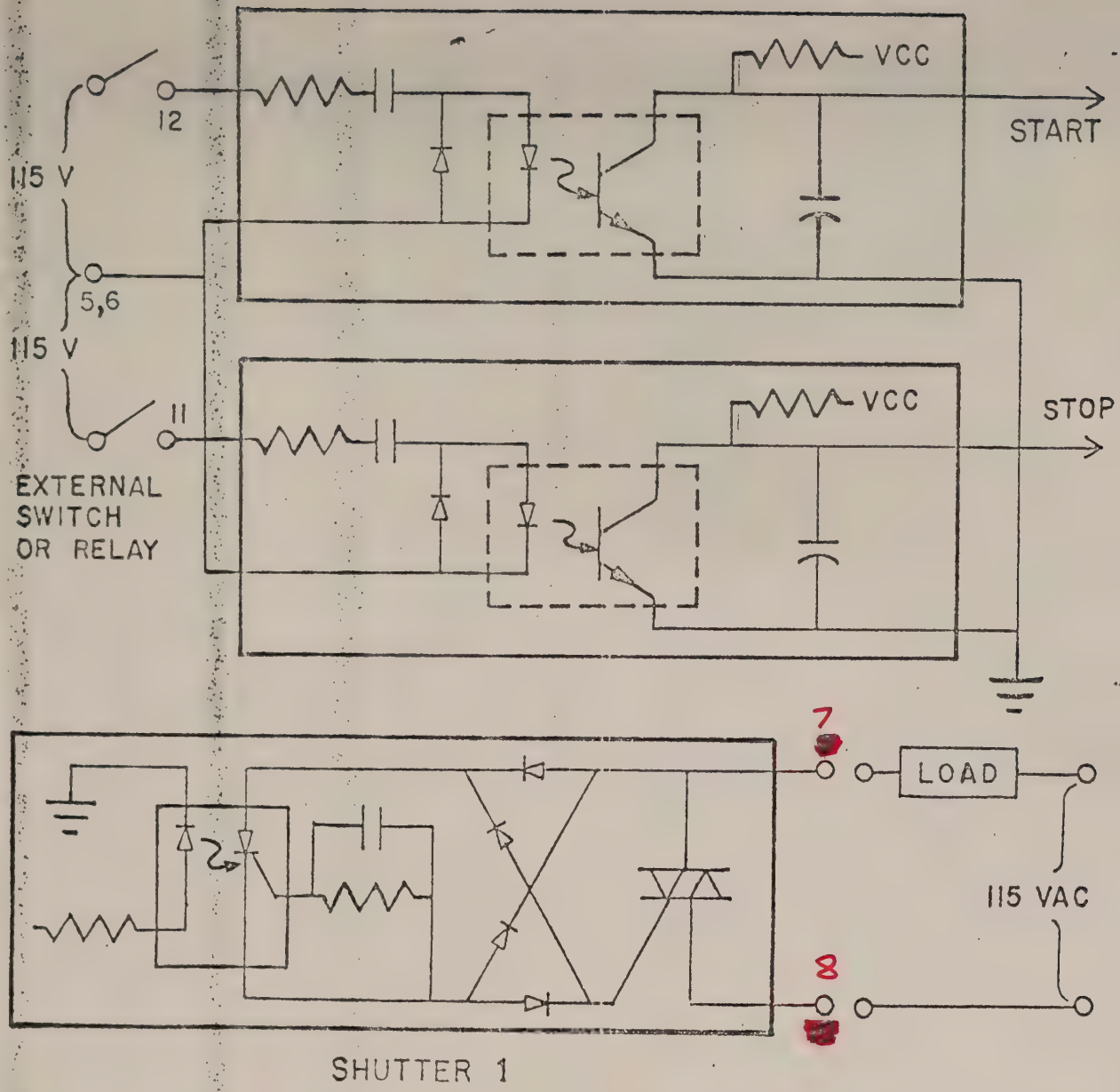


Figure 4-3 Interface Circuits

The outputs are also optically isolated with each circuit being independent (Figure 4-3). The triacs providing circuit closure are rated at 220 volts, 3 amps, and to insure reliability this rating should never be exceeded.

4.2.2 Source Power (J8)

Three separate control voltage outputs are supplied at the connector (Figure 4-4). The output ranges from 0 to -10 volts and is capable of driving a load current of 20 mA. These outputs are driven by optical isolators in order to effectively decouple the unit from external noise. It is possible, however, to bypass the optical couplers with a simple wire change on the XMS-330 circuit board (see Section 6.0). This is not a recommended mode of operation and should only be considered for special applications.

4.2.3 Sensor 1, 2, 3

The 321-40 oscillator cable, supplied with the XMS, is connected to these inputs. Each input is a separate circuit, and input selection is determined when programming the unit. The normally supplied length of the oscillator cable is 10 feet, and longer lengths are available by special order.

4.3 Installation of Sensor Head

The sensor head can be installed in any appropriate location in the vacuum chamber. It can be supported by the two 4-40 screws on the mounting bracket or by the water cooling tube alone. The cable length from the sensor head to the feedthrough should not exceed 40 inches. The water cooling tube should be cut to proper length and connected to the feedthrough by brazing or by using vacuum couplings. Shield the sensor cable from the radiation heat which comes from the evaporation sources or the substrate heater.

In installing the sensor head, the following precautions should be observed:

a. Water cooling is always recommended except for short depositions at low temperatures. For best stability the head temperature should not be allowed to exceed 85°C during operation. Approximately 0.2 gpm water flow should provide sufficient cooling for most applications.

Pin	Function
5	Control Source A
4	Control Source B
1	Control Source C
7	Control Reference
2	---
6	---
3	---
8	---
9	---

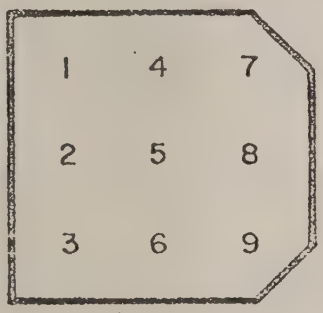


Figure 4-4 J8 Source Power

b. Place the sensor head as far as possible from the evaporation source, preferably more than 10 inches. For complete system calibration, see Section 5.0.

c. If the evaporating material spatters during deposition and a small droplet of molten material hits the crystal, damage to the crystal may result causing the oscillation to cease. Use a shutter to shield the sensor head during the initial soak period which will help alleviate the problem.

4.3.1 Replacing the Crystal

Grip the sensor head cap with fingers and pull it straight out by squeezing finger tips in between the lip of the cap and the water cooling tube. Use fingers or a pair of tweezers to pull the ceramic retainer straight out. Flip the cap over to remove the old crystal. Drop a new crystal into the cap with the patterned electrode facing back to make contact with the leaf springs on the ceramic retainer. Put the ceramic retainer back into the cap and snap the cap onto the body of the sensor head.

Observe the following precautions in handling and using the crystals:

a. Always use clean lab gloves or plastic tweezers for handling the crystal to keep it free from contamination.

b. Do not rotate the ceramic retainer assembly after it is seated as this will cause scratching of the electrode on the crystal and may result in intermittent or poor contact.

c. Certain materials, especially dielectrics, may not adhere strongly to the crystal surface and cause erratic readings.

d. It is normal for thick deposits of certain materials, such as SiO and Si to peel off the crystal when exposed to air. This is due to the change of film stress by gas aborption.

4.4 Final Programming

Refer to Section 3.0 for programming procedures. Several parameters in the final program must be determined by actual deposition:

Soak Power 1
Soak Power 2
Tooling Factor
Gain

It is suggested that a value of 10 be programmed for gain in the initial run. Adjustment of this parameter can be made during a controlled deposition, optimizing the value to achieve shortest acquisition time of desired rate and stable overall control. Soak power 2 should be set to a level which will achieve desired rate. This condition will also help in reducing the time required for establishing desired rate control. For calibration of tooling factor, density and Z-ratio, refer to Section 5.0.

Caution: If a test mode run is desired to check the unit out, the control voltage output signal exits at source power (J8) connector.

5.0 CALIBRATION

5.1 Theory of Operation

The evolution of commercial quartz-crystal film thickness monitors can be divided into three stages:

a. Frequency Measurement Techniques

The use of quartz-crystal resonator to measure deposited film thickness was first explored by Sauerbrey in 1957 and later developed into a commercial unit. The thickness frequency equation used is given by

$$T_f = -(N_q d_q / d_f f_q^2) \quad (f_c - f_q) \tag{1}$$

where

T_f = film thickness (cm)

d_q = density of quartz (g/cm^3)

d_f = density of film (g/cm^3)

$N_q = f_q l_q$ = frequency constant for AT-cut quartz crystal (Hz/cm)

l_q = thickness of quartz crystal (cm)

f_q = resonant frequency of unplated crystal (Hz)

f_c = resonant frequency of loaded crystal (Hz).

Extensive theoretical studies were made to derive Eq (1) with the assumption that the deposited mass is much smaller than the mass of the quartz crystal, or $(f_c - f_q)$ f_q. Experimentally, it was found that in order to keep the thickness measurement within a reasonable accuracy, the maximum frequency shift allowable by this technique is limited to about 2% of f_q.

b. Period Measurement Technique

The second generation quartz-crystal thickness monitors used the following equation for thickness computations:

$$T_f = (N_q d_q / d_f)\ (t_c - t_q) \qquad (2)$$

where $t_c = 1/f_c$ and $t_q = 1/f_q$ are the period of oscillation for the loaded and original crystals, respectively. It is apparent that for a small frequency shift Eq (1) becomes a good approximation of Eq (2). Although it has been experimentally demonstrated that Eq (2) is reasonably accurate for selected materials with frequency shifts of up to 10% of f_q, the theoretical justification of using Eq (2) for thickness computation was lacking. In addition, recent tests on validity of Eq (2) indicated that significant errors begin to appear for a majority of materials with crystal frequency shift as small as 5% of f_q. When the quartz crystal monitor is used to measure the rate of deposition, the errors in indicated rate become even more serious because the thickness error is a time varying function and rate is the derivative of thickness with respect to time.

c. Z-match Technique

Recent advances in crystal design and improved driving circuitry allow the quartz crystal to keep oscillating even with very large amounts of deposited material on it. In many cases frequency shifts of more than 20% of f_q can be achieved. Also, complex and precise mathematical calculations can be easily performed with modern digital circuitry. Therefore, if an exact thickness frequency equation can be found, an instrument can be developed which does not have to be a compromise between accuracy and crystal life.

Miller and Bolef were the first to treat the quartz-film composite as a one dimensional compound acoustical resonator. Their results indicated that the elastic properties of the deposited film should be related to the frequency shift. A further study on their original solution resulted in a simpler thickness frequency equation in the form of

$$T_f = (N_q d_q / \pi d_f f_c Z) \tan^{-1} Z \tan \pi (f_q - f_c)/f_q \qquad (3)$$

where

$$Z = (d_q \mu_q / d_f \mu_f)^{1/2}$$

is the acoustic impedance ratio with μ_f and μ_q the shear moduli of deposited film and quartz crystal, respectively. Eq (3) shows that materials with different elastic properties will obey different thickness frequency relations. This phenomenon has been verified experimentally in our laboratory for a number of materials.

The experimental results demonstrated that if the density and Z value of the deposited material are known, the film thickness can be determined to a remarkable accuracy by using Eq (3).

Another significance of Eq (3) is that for the first time the validity of "period measurement" technique, or Eq (2), can be explained from a theoretical point of view. Through a single algebraic exercise, one can easily show that Eq (2) is a special case of Eq (3) with Z = 1, or quartz on quartz.

The Inficon XMS uses the concept of a microcomputer and incorporates an approximated form of Eq (3) for thickness computation. The acoustic impedance ratio Z can be entered into the instrument as a separate material constant. A reproducibility of better than 2% for both thickness and rate can thus be achieved with no restrictions on the allowable frequency of the crystal.

5.2 Calibration Procedure

5.2.1 Density

Place a substrate with proper masking for film thickness measurement adjacent to the sensor head so that the same thickness will be accumulated on the crystal and this substrate. Set density to the bulk value of the film material or to an approximate value, Z-ratio to 1.000 and tooling to 100%. Place a new crystal in the sensor head and make a short deposition (1000-5000Å) by using the manual control. After deposition remove the test substrate and measure the film thickness with either a multiple beam interferometer or a stylus type profilometer. A new density value can be determined using the relationship:

$$\text{Density } (g/cm^3) = D_1 \frac{T_x}{T_{M_x}}$$

where D_1 = Initial density setting

T_x = Thickness reading on XMS

T_{M_x} = Measured thickness.

Program the XMS with the new density value and observe that the displayed thickness is equal to the measured thickness. Slight adjustment of density may be necessary in order to achieve $T_x = T_{M_x}$.

5.2.2 Z-ratio

A list of Z values for commonly used materials in thin film technology are given in Table 5-1. For other materials Z can be calculated from the following formula:

$$Z = (d_q \mu_q / d_f \mu_f)^{1/2}$$

$$= 8.834 \times 10^5 \, (d_f \mu_f)^{-1/2}$$

where d_f and μ_f are the density (g/cm^3) and shear modulus ($dynes/cm^2$) of deposited film, respectively. The densities and shear moduli of many materials can be found in a number of handbooks.

Table 5-1
Z VALUES FOR COMMON MATERIALS

Material	Z
Pb	1.125
Al	1.077
SiO_2 (amorphous)	1.066
Ti	0.627
Ag	0.529
Zn	0.511
Cu	0.437
Au	0.381
Ni	0.332
Pt	0.239

Results obtained in our laboratory indicated that the Z values of materials in thin film form are very close to the bulk values. However, for high stress producing materials, Z values of thin films are slightly smaller than those of the bulk materials. For those applications where more precise calibration is required, the following direct method is suggested.

Using the calibrated density and 100% tooling, make a deposition such that the percent crystal life display will read approximately 50% or near the end of crystal life for the particular material, whichever is smaller. Place a new substrate next to the sensor head and make a second short deposition (1000-5000Å). Determine the actual thickness on the substrate as suggested in density calibration. Adjust Z-ratio value in the XMS to bring thickness reading in agreement with actual thickness.

For multiple layer deposition, for example two layers, the Z value used for the second layer is determined by the relative thickness of the two layers. For most applications the following three rules will provide reasonable accuracies:

a. If the thickness of layer 1 is large compared to layer 2, use material 1 Z value for layer 2.

b. If the thickness of layer 1 is thin compared to layer 2, use material 2 Z value for layer 2.

c. If the thickness of both layers are similar, use a value for Z-ratio which is the weighted average of the two Z values for deposition of layer 2.

To achieve the ultimate in precision, a multiple sensor head arrangement with appropriate shuttering is necessary.

5.2.3 Tooling

Place a test substrate in the systems substrate holder. Make a short deposition and determine actual thickness. Calculate tooling from the relationship:

$$\text{Tooling (\%)} = 100 \times \frac{T_{M_S}}{T_X}$$

where T_{M_S} = Actual thickness at substrate holder

T_X = Thickness reading in XMS.

The percent tooling may be entered into the XMS program and observe $T_{M_S} = T_X$. Slight adjustment of this value may be necessary in order to satisfy the equality.

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